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ABSTRACT

This review surveys documents and journal articles previously announced in RIE and CIJE that deal with the principles and techniques of sound transmission and control, particularly as they relate to school environments. School planners and administrators are advised that excessive acoustical insulation costs may be avoided by early decisions pertaining to site selection, arrangement of school buildings, and grouping of areas within the school. Nine of the documents surveyed are available from the ERIC Document Reproduction Service. (Author)

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Acoustical Environments

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School design which hampers audio-communication has failed in fulfilling one primary purpose for the building. However, it is insufficient to think in terms of avoiding poor acoustics; rather, available skills and technology should provide a design in which the acoustical characteristics consciously and deliberately contribute to and enhance the activities in the various spaces of the school. To accomplish this goal, consideration of acoustical needs should be part of the development of the project from programming through the stages of design to construction and equipment installation.

Rensselaer Polytechnic Institute (1966)

Good acoustics in a school facility result from a combination of design features, many of which require foresight on the part of school planners and administrators. Because provision for an adequate acoustical environment begins with a building's planning and design, those educators engaged in the planning process should be alert to basic principles of sound transmission and control.

Educators should examine the site, landscaping, and design of a proposed facility in terms of the noise generation and noise tolerance levels of various school activities. Excessive acoustical insulation costs may be avoided by early decisions pertaining to site selection, arrangement of school buildings, and grouping of areas within the school. Careful selection and arrangement of furnishings may significantly reduce the adverse effects of sound reverberation within a teaching space. Deliberate use of "masking sounds" (for

example, background music) can be helpful in concealing intermittent and distracting sounds such as conversation from adjacent areas, equipment noise, and chair scraping.

These and other solutions in which the educator may be instrumental receive attention in much of the literature surveyed in this review. Some documents explain for architects and planners various special problems and technical data pertaining to school building acoustics. A supplementary bibliography provides additional references (primarily to recent journal articles) on sound control in school buildings.

Nine of the documents reviewed are available from the ERIC Document Reproduction Service. Complete instructions for ordering are given at the end of the review.

ACOUSTICS AND THE SCHOOL BUILDING

A publication by the Rensselaer Polytechnic Institute (1966) gathers and organizes acoustics information for use by school architects and administrators. The document emphasizes two basic attitudes necessary to the analysis, planning, and construction of school facilities: acoustics must be thought of as more than "removal of noise," and the concept of acoustics as an "after the fact" curative for sound problems should be replaced by consideration of acoustical principles at every level of architectural design.

These guidelines provide an understanding of basic acoustical principles, describe analytic measurement techniques, and identify sound problems demanding a greater degree of technical skill. Six basic acoustical planning prerequisites are identified:

- describe sources of off-site noise, such as highways or commercial areas, and prescribe acceptable noise levels within the school building. In his design, the architect must see that the off-site noise is controlled and reduced by appropriate sound barriers
- note noise-producing activities which must be accommodated on the site and the problems of location for acoustical compatibility
- define acceptable noise levels for corridors, lobbies, and other circulation areas
- describe the kinds of functions an auditorium will be expected to house—lectures, motion pictures, plays, choral music, instrumental music, or whatever—and therefore the acoustical characteristics it must exhibit
- note classroom uses of instructional aids and media—films, records, television—and the accompanying acoustical planning considerations
- define acoustical qualities for general classrooms in terms of allowable ambient noise and desirable reverberation time

Illustrations accompany information about acoustics and architectural programming, school planning, facilities design, and noise control. The special requirements of large-group spaces, music rooms, flexible and open plan facilities, and sound systems are treated in detail. A chart groups many useful recommendations concerning room shape and absorption materials for a variety of school areas. An extensive checklist summarizes important acoustical considerations for planners and administrators.

The acoustical environment of schools designed to meet the spatial requirements of new teaching methods receives attention in a report by Fitzroy and Reid (1963). They describe the results of an Educational Facilities Laboratories field study in which

questionnaires dealing with the aural environment were sent to teachers in thirty-seven schools across the country. The study sought to define acoustical design criteria for flexible classrooms that would identify minimum acoustical separation required for effective group and individual work, tolerable sound levels, and objectionable types of sound. Acoustical consultants analyzed each school to determine the characteristics of noise reduction, reverberation, speech interference levels, and articulation indexes. The authors present collected data, discussion, and conclusions for each school studied.

Kingsbury and Taylor (1967) explain important design factors governing speech perception in the classroom. The provision for optimum reverberation time is illustrated by graphs indicating the additional acoustic absorption necessary for a variety of classroom sizes and occupancies. The "articulation index" is described as representing the proportion of the normal speech signal intelligible to the listener. Other factors to be considered in acoustical calculations are the nature of the speech spectrum, attenuation of the speech signal before reaching the ear, and the effects of noise in masking the signal.

Starting with known facts and assumptions, the authors determine noise-level limits for effective speech communication across various speaker-listener distances typical of classrooms. In addition to considering sound transmission loss under maximum noise levels, they graph the loss properties required of exterior and interior walls for several exterior noise conditions.

An early article in *Nation's Schools* (McKay 1966) discusses noise levels and acoustic design for schools. For an optimum acoustic environment, he recommends all parts of a construction system be well balanced. Carpeting, for instance, may reduce the need for other acoustic materials while also cutting down on footfall and chair-scraping noise. Absorptive materials used in classrooms can be much thinner than those used in music rooms, auditoriums, and shops where a thicker material and air space is required.

Site Planning Techniques for Controlling Unwanted Sound

The **building complex** can be planned on the site so as to reduce the acoustical interference from surrounding elements, perhaps by placing part of the structure below grade or eliminating windows.

Landscaping can be planned to reduce traffic noise, and other disturbances.

Terrain features can be introduced to further reduce acoustical interference—earth taken in digging foundations can be used to mold a hill or rise as a barrier to external noise.

Parking lots, entrance roads, and school bus loading and unloading zones can be planned to be as remote as possible from classrooms, libraries, and other "quiet areas."

Playgrounds and athletic fields can be located in remote areas of the site or positioned so that acoustical barriers in the form of landscape, solid walls, or other building elements separate them from academic spaces.

Outdoor sitting areas, and circulation and "collecting areas" associated with auditoriums and cafeterias, can be located so as not to interfere with the quiet areas of the school.

Finally, the **School Board** can work with local planning agencies in developing a master plan which will insure that proper land use retains acoustically appropriate sites.

Rensselaer Polytechnic Institute (1966)

McKay stresses the relationship between a room's proportions and its acoustics, observing that rehearsal rooms for large musical groups should be at least fifteen, and preferably as much as twenty-five, feet in height. Speech classrooms should be about thirty feet square by ten feet high. He suggests auditoriums be built with audience and performing platform within the same space and under a continuous ceiling. To ensure consistently high quality acoustics, particular attention must be given to the proportions of flexible spaces.

Sound control techniques used in construction of a new school and renovation of an existing facility are reported in *The American School Board Journal* article ("How To Design a Quiet School" 1968). A general discussion of noise problems in school districts and teaching situations includes sound control for areas where there is a high level of exterior noise.

The article explains for educators differences among sounds and advises planners to analyze sound control problems of each building individually. Typical acoustic solutions used in the two schools examined are given:

forced air ventilation systems

exterior walls of reinforced masonry or tiltup concrete

sealed and glazed glass windows

acoustical tile ceilings

placement of doors and windows designed to minimize corrective sound measures

EVALUATION

A recent speech by Walsh (1971) describes a rating system for evaluating the acoustical environment of existing school facilities. He outlines survey techniques used in a study of San Francisco schools and gives information pertaining to unit costs for corrective work and cost-benefit tables for comparative analysis.

In comparing various instructional practices and problems of open plan classrooms with those of conventional plan schools, Kyzar (1971) found that taking down walls does not necessarily contribute to noise pollution. A survey of the amount of noise transmitted between instructional areas indicates that noise is not a significant problem in open space schools.

Turner (1970) reports on a survey of sound levels taken in several Texas schools to determine the amount of noise and sound presented by class size, activity type, building location, air conditioning, and large amounts of glass. He found that class size and relative amounts of glass had little bearing on the production of noise in a classroom. Sound levels were most affected by the nature of the classroom activity. Air conditioning and building location with accompanying exterior noise levels also proved to have significant effect on noise levels. Turner emphasizes that school planners, in an attempt to abate noise levels, should pay more attention to the acoustical environments of their buildings.

Reporting on the effects of school noise conditions on student written task performance, Slater (n.d.) observes that written tasks of relatively short duration are not affected by peaks of noise typically found in a normal school environment. Her study examined performance under irregular interval noise, average or normal noise, and quiet conditions. Questionnaires were used to determine perceptions of noise and to measure anxiety. She found no significant differences in speed and accuracy on test

scores, and no significant relationship between performance and measures of anxiety and perception.

Use of Modified Rhyme Test (MRT) tapes to test speech intelligibility in three classroom spaces is described in a report by Kingsbury and Strumpf (1969). The authors also investigated the expected signal attenuation over distance and the effect of added noise on speech perception. Drawing from the results of these tests, they present a set of acoustic guidelines for improving speech perception in actual classrooms.

Related Literature

Yerges (1969) discusses principles and techniques of controlling acoustical environments in terms of human, environmental, and building needs. In addition to definitions of the nature of sound and its variables, his book contains methods for planning, designing, and reorganizing facilities to incorporate proper acoustic functions and materials. He also reviews building and mechanical sound control in conjunction with a variety of sound properties, including transmission, barriers, control, reinforcement, and absorption. Performance criteria are cited together with legal, medical, and trouble-shooting aspects of the sound environment. The book is amply supplemented with tables, charts, drawings, checklists, and references.

Parkin and Humphreys (1969), a scientist and an architect, explain the physical concepts needed in any appreciation of acoustical problems. Their treatment of the subject covers:

- the nature of sound and its behavior in rooms
- general principles and practices of sound insulation and noise control
- design of studios and rooms for speech-reinforcement systems
- sound measurement and calculation
- criteria for noise control and sound insulation

Many building plans, sketches, tables, graphs, and photographs aid in explaining basic concepts of the acoustical environment.

The Acoustical Materials Association (1965) bases its discussion of the primary function of acoustical materials (control of sound by sound absorption) on the wave and energy properties of sound. The document observes that, in general, sound control in spaces such as offices and classrooms requires a larger volume of acoustical material than is required by auditoriums, where a certain amount of reverberation and sound reflection is beneficial. In addition to describing procedures for reducing sound transmission from outside sources, the report examines important properties of materials such as maintainability, flame spread, and fire resistance. Appendixes include definitions of scientific terms, charts, and sound absorption coefficients of building materials and furnishings.

A publication by the Lead Industries Association (1965) suggests that proper use of lead in combination with other materials can both compensate for their deficiencies and improve the acoustical performance of the composite barrier. Lead provides a good combination of the properties required for an ideal sound barrier: high density, freedom from stiffness, good damping capacity, and integrity as a nonpermeable membrane. The document discusses techniques for improving sound barriers through use of lead and describes ways in which barriers are rated for their effectiveness. Also given are guidelines for installing practical lead walls.

A brief paper by Kingsbury and Wallace (1968) shows a variation in acoustic absorption between informally dressed college students in typical classroom seating and formally dressed audiences in upholstered seating. It is theorized that this variation is due to differences in clothing, but further study is recommended. In addition to presenting the technical data relevant to their study, the authors describe an inexpensive acoustic simulator of people that can be used to approximate the effects of occupancy in similar situations.

An annotated bibliography by Doelle (1965) classifies the field of architectural acoustics into a comprehensive system of interrelated topics. The document is divided in three parts: general architectural acoustics; room acoustics—auditoriums for speech, rooms for music, studios, places for assembly with mixed acoustical requirements; and noise control. Theoretical aspects of architectural acoustics and mathematical data have been reduced to a minimum in the annotations. Doelle stresses the close relationship between acoustical performance and architectural expression and gives particular attention to the specific needs of those responsible for building design.

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